REMARKS

Applicant respectfully request favorable reconsideration of this application. Claims 1-10 are pending.

Claim Rejections - 35 USC § 103

Claims 1-6, 8, and 10 were rejected under 35 USC 103(a) as being unpatentable over Buon (US 4494548) and further in view of Nunomura et al. (US 7001355 B2). Applicant respectfully traverses the rejection.

Regarding claim 1, the rejection conceded that Buon does not teach a device that includes a 1,2-butylene glycol or 1,3-butylene glycol. The rejection also conceded that Nunomura et al. does not specifically mention 1,2-butylene glycol. The rejection stated that because 1,2-butylene glycol and 1,3-butylene glycol are isomers, it would have been obvious for one of ordinary skill in the art to substitute one isomer for another in order to achieve a predictable result. Applicant respectfully disagrees.

Buon teaches a device with a fill fluid. To work as intended, Buon's fill fluid must have certain characteristics. Buon teaches that the "fill fluid must also be capable of lubricating the mechanism which it contacts, i.e., the bearings 13 and 18, the cam 13, etc. and chemical compatible with the materials within the probe to which it is exposed as well as being electrically insulating. An example of such a fluid is composed of 71% propylene glycol and 29% Poly G-200" (column 2, lines 57-63). Further, Buon teaches that the fluid is sealed with a pair of O-rings in the internal body (see column 2, lines 64-65). Accordingly, Buon's device requires that the fluid be sealed inside the device to lubricate the mechanical parts of the device from within and further that the fluid must be electrically insulating.

Nunomura et al. does not teach a "fill fluid" that has the requirements that Buon teaches are necessary for the device to work as intended. Nunomura et al. teaches a viscous composition for applying on the skin (column 4, line 57). Nunomura et al. teaches that the viscous composition include a water-soluable humectant and an aqueous carrier. Nunomura et al. does not even suggest that the viscous composition can be used inside an ultrasonic device, let alone suggest that it is capable of lubricating mechanical parts, such as "bearings" and "cams" (as required according to Buon, see supra). Nunomura et al. teaches that the composition includes

"0.1% to about 30%" water-soluable humectant (column 11, line 14). The water-soluable humectant contains butylene glycol which is specifically and singularly defined, without alternatives, to be 1,3-butylene glycol (column 11, line 17, and again in line 38). Nunomura et al. teaches that 1,3-butylene glycol provides a moisturizing effect to skin without significantly deteriorating the penetration of skin lightening agents (column 11, lines 34-36). Further, the water-soluable humectant 1,3-butylene glycol is provided in an aqueous carrier comprising "at least about 70% water" (column 12, line 26). Accordingly, the composition taught in Nunomura et al. is not intended to be sealed inside a device to lubricate the mechanical parts of the device from within. Thus, filling Buon's device with the composition taught in Nunomura et al. would be contrary to the stated purpose of the composition in Nunomura et al. Therefore, there is no motivation to combine the two references.

Further, the rejection erroneously concluded that it would have been obvious for one of ordinary skill in the art to substitute one isomer for another in order to achieve a predictable result. Although it is known in the art that certain physical properties of particular isomers of butylene glycols are similar, for example, 1,3-butylene glycol, 1,4-butylene glycol, and 2,3-butylene glycol have similar physical properties, it is also known that 1,2-butylene glycol has physical properties that are significantly different from the other three isomers. The difference is generally attributed to the more hydrophobic nature of 1,2-butylene glycol compared to the other isomers of butylene glycol (see Hawrylak, Brent, et al. *Ultrasonic Velocity and Volumetric Properties of Isomeric Butanediols plus Water Systems*, Can. J. Chem. 76: 464-468 (1998), at 468). Further example is in the viscosities of 1,2-butylene glycol and 1,3-butylene glycol, which are significantly different from eachother (see Table I of Hawrylak, Brent, et al., *Viscosity, Surface Tension, and Refractive Index Measurements of Mixtures of Isomeric Butanediols with Water,* Journal of Solution Chemistry, Vol. 27, No. 9, 1998: 827-841, at 829). As shown in Fig. 2 of Hawruylak et al., 1,3- butylene glycol (1,3-BTD), 1,4- butylene glycol (1,4-BTD), and 2,3-butylene glycol (2,3-BTD) show similar $\Delta\eta$ values while that of 1,2- butylene glycol (1,2-BTD) is clearly different from the other isomers (see Id, at 834; figure is shown below). Accordingly, because of these differences, one skilled in the art would understand that substituting 1,2-butylene glycol for 1,3- butylene glycol does not achieve a predictable result. Thus, it would not have been obvious for one of ordinary skill in the art to substitute 1,2- butylene glycol for 1,3-

butylene glycol. As noted above, Buon's device requires a "fill fluid" that is sealed inside the device to lubricate the mechanical parts of the device from within and further that the fluid must be electrically insulating. Nunomura et al. does not teach whether the "fill fluid" has these requirements that are necessary for the device to work as intended. Therefore, there is no motivation to combine the two references. Further, even if there was a motivation to use a 1,3-butylene glycol in Buon's device, there is no reference that teaches the use of 1,2-butylene glycol as a "fill fluid." Further, as stated above, it would not have been obvious for one of ordinary skill in the art to substitute 1,2- butylene glycol for 1,3- butylene glycol. Therefore, claim 1 is patentable over Buon in view of Nunomura et al. Claims 2-6, 8, and 10 are patentable for at least the same reasons as claim 1 from which they depend. Applicant respectfully requests a favorable reconsideration.

834 Hawrylak et al.

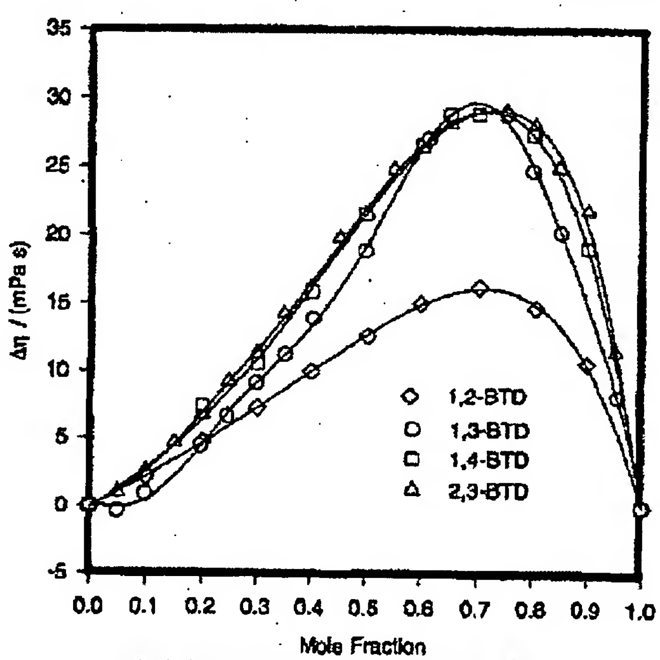

Fig. 2. Plot of Δη vs. mole fraction of diol at 25°C.

Fig. 2 of Hawrylak et al., at 834 (1,2-BTD is 1,2-butylene glycol)

Claim 7 was rejected under 35 USC 103(a) as being unpatentable over Buon, in view of Nunomura et al., and further in view of Ludwig (Ludwig, George. The Velocity of Sound through Tissues and the Acoustic Impedance of Tissues. The Journal of the Acoustical Society of America, Nov. 1950: (22)(6) 862-866) and in view of Schafer (Schafer, Mark E et al. Use of Time Delay Spectrometry in Fluid Attenuation Measurement Ultrasonics Symposium, 1989: 973-976). Applicant respectfully traverses the rejection. Neither Ludwig nor Schafer remedy the deficiencies of Buon and Nunomura et al. stated above in regard to claim 1. Thus, claim 7 is patentable for at least the same reasons as claim 1 from which it depends.

Moreover, the rejection stated that Schafer teaches the acoustic attenuation properties of 1,3-butylene glycol and accordingly it would have been obvious for one of ordinary skill in the art to understand the attenuation properties of fluids as taught in Schafer and to modify the system of Buon and Nunomura et al. to include the desired fluid as taught in Schafer in order to chose the ideal fluid. Applicant respectfully disagrees.

Schafer et al. teaches that finding or choosing an ideal fluid that meets certain acoustic constraints that is also "non-corrosive, non-conductive, and have suitable dielectric and viscosity characteristics" is not only non-obvious, "it is nearly impossible" (Schafer et al., at 973, Part I). Schafer et al. also states that the results have a trend wherein "more viscous fluids generally showed higher levels of attenuation" (Schafer et al., at 975, Part V). Schafer et al. does not support this statement with any numerical values, graphs, or data. Accordingly, this statement is merely a general statement regarding an observed trend of the few tested fluids, not a theory that correlates fluid properties. This is supported by the fact that it is well known in the art that viscous fluids do not necessarily show higher levels of attenuation. For example, Selfridge (IEEE Transactions on Sonics and Ultrasonics, Vol. SU-32, No. 3, May 1985: 381-394) teaches attenuation values of certain fluids (indicated as LOSS(A=) on pages 388-390). Further, the viscosities of certain fluids are known in the art, see for example page 394 of Chronological Scientific Tables, vol. 75 (2002, edited by National Astronomical Observation of Japan). The following table shows several fluids' attenuations and viscosities, selected from the above two documents.

Liquids	CAS No.	Viscosity (10^{-3} Pa·s)	LOSS (A=)	Temperature (°C)
Acetone	67.64.1	0.31	54	25
Alcohol, methanol	67.56.1	0.543	30.2	25
Benzene	71.43.2	0.603	873	25
Alcohol, ethanol	61.17.5	1.084	48.5	25

As shown in the above table, acetone has a viscosity of 0.31 and attenuation of 54 while ethanol has a viscosity of 1.084 and attenuation of 48.5. Accordingly, acetone has lower viscosity than ethanol yet exhibits higher attenuation. Furthermore, ethanol has a higher viscosity than benzene, yet benzene has a substantially higher attenuation than ethanol. Accordingly, the examples above contradict the presumption relied in the rejection.

As shown above, it is known in the art that a fluid having lower viscosity than another fluid does not necessarily also have lower attenuation. Thus, it would not have been predictable that replacing 1,3-butylene glycol with 1,2-butylene glycol as an acoustic medium would result in the desirable attenuation. Accordingly, even if the viscosities of 1,2-butylene glycol and 1,3-butylene glycol were known, one skilled in the art would not be able to predict which would have higher attenuation. Thus, the rejection erroneously relied on this general statement to conclude that there is a relationship of viscosity to attenuation that would make one skilled in the art to predict that 1,2-butylene glycol would have lower attenuation than 1,3-butylene glycol.

The acoustic impedance of 1,2-butylene glycol is superior to and more desirable than 1,3-butylene glycol because the acoustic impedance of 1,2-butylene glycol is similar to the acoustic impedance of a living body (see page 8, lines 17-18 in the Specification). Because of this and other unexpected and superior acoustic characteristics of 1,2-butylene glycol, "an ultrasonic probe with high performance, high quality, and safety can be obtained. In particular, since 1,2-butylene glycol produces a small amount of ultrasonic attenuation, it is possible to improve the transmitting/receiving sensitivity for ultrasonic waves" (page 10, lines 12-15; also see Fig. 2). Further, Fig. 3 illustrates clearly the superior viscosity characteristics of 1,2-butylene glycol over that of 1,3-butylene glycol for use as an acoustic medium.

For at least the above reasons, claim 7 is patentable over Buon, in view of Nunomura et al., and further in view of Ludwig and in view of Schafer. Applicant respectfully requests a favorable reconsideration.

Claim 9 was rejected under 35 USC 103(a) as being unpatentable over Buon, in view of Nunomura et al., and further in view of Atala et al. Applicant respectfully traverses the rejection. Atala et al. does not remedy the deficiencies of Buon and Nunomura et al. stated above in regard to claim 1. Thus, claim 9 is patentable for at least the same reasons as claim 1 from which it depends. Applicant respectfully requests a favorable reconsideration.

In view of the above amendments and remarks, Applicant respectfully requests a Notice of Allowance. If the Examiner believes a telephone conference would advance the prosecution of this application, the Examiner is invited to telephone the undersigned attorney-of record, Douglas P. Mueller (Reg. No. 30,300), at (612) 455-3804.

Respectfully submitted,

53148
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Approximate Material Properties in Isotropic Materials

ALAN R. SELFRIDGE, MEMBER, IEEE

Abstract—A very important part of the design of ultrasonic transducers and ultrasonic measurement systems is the selection of materials. Typically, materials must be screened on the basis of their acoustic velocity, impedance, and attenuation. The final selection of a material is based upon many other factors, such as how well it adheres to epoxy, its linearity, or how much water it absorbs. This paper is intended to aid in the initial screening process. Some simple techniques for approximating these material properties are presented, and then an extensive table of the materials that have been measured or whose properties have been obtained from the references is given.

Measurement Techniques

THE FIRST STEP in the measurement of acoustic properties is to prepare a sample of the material of interest. Typically, the sample should have a thickness of approximately ten wavelengths at the measurement frequency and lateral dimensions at least ten times the thickness. The major surfaces should be flat and parallel to within about one percent or less of the thickness. If the material is cast, then special care must be taken to lap or sand the sample sufficiently to remove any variation in thickness due to shrinkage during cure.

Once the sample has been prepared, it is mounted in a measurement system such as the one shown in Fig. 1. The system consists of a water tank, an ultrasonic transducer, and a gimbal jig. The water tank shown has a glass-plate bottom to facilitate alignments in these and other experiments. The ultrasonic transducer used in this case was a Panametrics Videoscan Immersion Transducer (reference number V310), with a center frequency of 5 MHz and an element diameter of 0.25 in. Obviously one should choose a transducer with a center frequency close to the frequency of interest. The element in the transducer should be flat and have lateral dimensions at least ten times the acoustic wavelength in the water. This is important to avoid having to make corrections for diffraction. The gimbal jig in the measurement system is used to mount the sample and to align the major surfaces perpendicular to the ultrasound beam. It is desirable to design this jig such that the axes of rotation intersect near the front surface of the sample, and thereby keep the distance between the sample and the transducer nearly constant during alignment. Alignment is done after the sample is mounted by iteratively rotating the sample on the axes shown in Fig. 1 until the echo amplitudes are maximized.

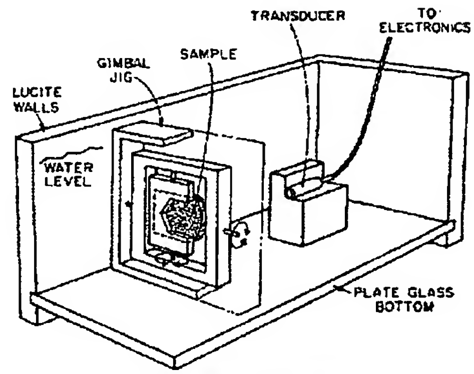

Fig. 1. Measurement tank.

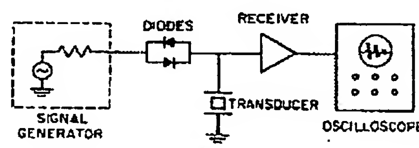

Fig. 2. Measurement system.

The electronic system used to make the acoustic material measurements is shown in Fig. 2. This consists of a signal generator, a pair of diodes, the transducer, a receiver amplifier, and an oscilloscope. The signal generator must be capable of generating a gated sine wave with adjustable frequency and fairly small duty cycle, typically one percent or less. The small duty cycle is important so that the tonebursts can be short, typically five cycles, with a repetition rate low enough for all the reverberations in the measurement system to be well damped before the next excitation pulse is generated. It is helpful to place a pair of silicon diodes, back-to-back as shown in Fig. 2, in series with the signal generator. These have the effect of significantly improving the signal-to-noise ratio at the output of the system by removing the loading effect of the characteristic impedance of the signal generator from the transducer on receive, as well as isolating any low-level noise from the signal generator into the receiver amplifier. The

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diodes are relatively unimportant on transmission when the signal levels are significantly higher than the threshold voltage of the diodes. One must be sure however that all of the received echos have amplitudes less than 1.0 V peak-to-peak to avoid any nonlinearities in the receiver amplifier. Linearity can be verified by adjusting the signal generator amplitude and observing that all received echos vary in proportion to one another. The receiver is typically a 20- to 40-dB high input impedance amplifier with a diode-protected input stage. A Panametrics 5052PR or 5052UA will work very well in this application. The oscilloscope must be capable of measuring time intervals and relative voltages with an accuracy of one percent or better.

Once the material specimen is prepared and the measurement system is assembled, the measurements are carried out as follows. The specimen is put into the gimbal jig and the ultrasonic transducer is mounted nearly normal to a major surface of the sample. The distance between the transducer and the specimen is chosen so that the transit time of an acoustic signal passing between the specimen and the transducer is about four to five times the transit time of an acoustic signal passing through the specimen. Next the signal generator is set to the frequency of interest and then gated to produce tonebursts approximately five cycles long. A train of echos due to reverberations of ultrasound in the specimen and water path between the specimen and the transducer should be observed on the oscilliscope. The amplitude of the echo train should then be maximized by manually adjusting the alignment of the specimen with respect to the ultrasonic beam using the gimbal jig.

If the material specimen is a typical epoxy with an impedance about twice that of water, and the measurement is set up and carried out as described earlier, then an echo train similar to that shown in Fig. 3 should be observed. The first four tonebursts in the received signal, denoted A_1, A_2, A_3, and A_4, are due to the wave that has traveled once through the water between the transducer and the specimen. A_1 is due to the reflection off the front face of the specimen. A_2 is due to the reflection off the back face of the specimen, and A_3 and A_4 are due to reverberations within the specimen. The next group of four tonebursts in the echo train are mainly due to triple transit echos, which traveled to the specimen, reflected back to the transducer, reflected back off the transducer, and traveled once again to the specimen, where reflections and reverberations occurred as before.

This rather complicated situation is analyzed using the schematic drawing in Fig. 4. We launch a signal from the acoustic transducer with a stress amplitude of one in the water. This signal propagates through the water path until it hits the impedance discontinuity at the sample–water interface. The reflection coefficient at this interface (R_1), is real and is given by (1). This equation and (2) can be derived from an example given by Auld [1, p. 130]. It is also given by Ristic [2, p. 11]. The portion of the signal that is reflected gives rise to the toneburst in the pulse train with the amplitude A_1. Z_s is the acoustic impedance

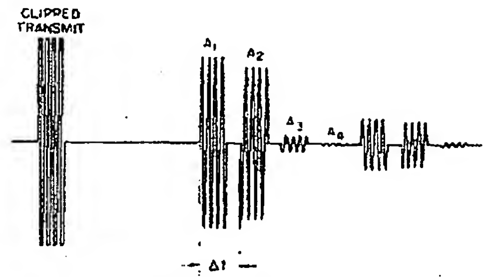


Fig. 3. Measurement signal.

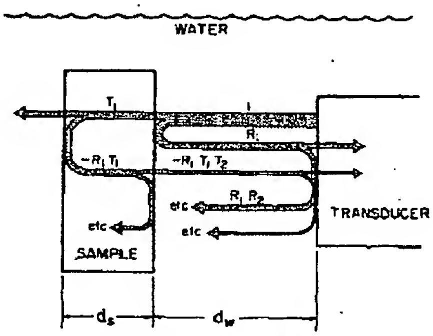


Fig. 4. Reverberation paths.

of the sample, and Z_w is the acoustic impedance of water:

$$R_1 = \frac{Z_s - Z_w}{Z_s + Z_w}. \tag{1}$$

Some of the ultrasound continues on into the material sample. The stress amplitude of the transmitted wave is given by the transmission coefficient (T_1) given by

$$T_1 = \frac{2Z_s}{Z_s + Z_w} = 1 + R_1. \tag{2}$$

A portion of the ultrasound which continues into the sample is lost through the back face of the sample, and the rest is reflected by the back surface towards the front again. The reflection coefficient found at the back face is simply $-R_1$. When this portion of the ultrasound reaches the front face of the sample again, part of it is reflected back into the sample, but some of it is transmitted back into the water toward the transducer. The transmission coefficient here (T_2), is given by

$$T_2 = \frac{2Z_w}{Z_s + Z_w} = 1 - R_1. \tag{3}$$

This portion of the ultrasound, which has been to the back face of the sample and is now traveling back to the transducer, gives rise to the toneburst in the pulse train with amplitude A_2.

Unless the acoustic transducer is perfectly matched to

the water, some of the ultrasound that returns to the transducer will be reflected back to the sample. This is the explanation for the subsequent groups of tonebursts observed in the pulse train shown in Fig. 3. The reflection coefficient off the transducer (R_2) is a complex function of frequency. This is why it is desireable to totally immerse the sample in water rather than the transducer in direct contact with it. If one is going to get accurate measurements of acoustic attenuation in a material, it is necessary to know the reflection coefficients on both sides of it.

While the sample is in the water tank and aligned, both the amplitudes A_1 and A_2 are recorded as well as the time delay between them, Δt. The time delay Δt corresponds to the propagation time of the acoustic signal in the sample. When measuring this time delay it should be noted that A_2 is inverted with respect to A_1. This means that if one uses a positive-going first break as the time reference for A_1, one should see a negative-going first break for A_2. Very often lossy materials will distort A_2 and make time determinations difficult. Some oscilloscopes, such as the HP1743, allow you to overlap two separately delayed traces and thereby obtain time-delay measurements with a high degree of accuracy, provided you include the effect of the phase inversion.

The next step in the sequence of measurements is to remove the specimen from the water tank and measure its thickness d with a micrometer. With the propagation delay of the acoustic pulse trough the specimen together with its thickness it is now possible to calculate the longitudinal plane wave velocity V in the specimen as

$$V = \frac{2d}{\Delta t}. \tag{5}$$

The density of the sample is determined next. This can be done either by weighing a known volume of the sample or, if the volume cannot be readily determined by Archemides' method. Archemides' method requires the weight of an object in water W_w and its weight in air W_a. If the material has a density less than 1.0 g/ml, the sample will need to be tethered to a known weight so that its own negative weight in water can be calculated. After these two weights have been determined we calculate the density p as

$$p = \frac{W_a}{W_a - W_w}. \tag{6}$$

The acoustic impedance of the same (Z_s) can not be calculated to be

$$Z_s = pV. \tag{7}$$

Convenient units for expressing typical acoustic velocities are mm/μs. The velocity of water is very close to 1.5 mm/μs. Density is conveniently expressed in g/ml. The product of these two unit choices gives impedances in MRayls (kg/(s $\times$ m^2)) $\times$ 10^6. The impedance of water in these units is very conveniently 1.5. Given Z_s and Z_w it is now possible to calculate R, T_1, and T_2, as given in (1)–(3). Given these values it is possible to calculate what the ratio between A_2 and A_1 should be, given that there is no loss in the sample:

$$\text{calculated } \frac{A_2}{A_1} = T_1 * T_2 = 1 - R ** 2. \tag{8}$$

To actually obtain the loss (in dB/cm) in the sample material we compare the measured ratio of A_2 to A_1 to the above calculated ratio as in

$$\text{Loss in dB/cm} = 20 * \log \left(\frac{\text{Calculated}\frac{A_2}{A_1}}{\text{Measured}\frac{A_2}{A_1}} \right) \Big/ (2 * d). \tag{9}$$

If the previously mentioned rules specifying the size of the transducer and sample are followed, then the correction required to (9) due to diffraction is only on the order of 1 dB. Typically, this can be ignored when calculating approximate material properties. However it is highly recommended that after setting up the describd measurement system, and before trusting the attenuation results obtained with it, a sample of plate glass or fused silica must be measured in which the loss is known to be very low relative to what can be measured with this technique. Obviously, if the measured value of the loss is more than about 1 or 2 dB/cm, the assumptions previously made concerning diffraction are suspect. This in turn means that the beam pattern of the transducer is suspect. Stanke [3] has actually measured materials which appeared to have acoustic gain rather than acoustic loss! The distorted beam pattern of the commercial transducer he was using was in fact responsible for this observation, rather than some more interesting miracle. To get over this problem special transducers were constructed using PVF2 on brass backings. The reflection amplitude of these devices was measured as a function of the distance between the transducer and a flat plate reflector, and this function was shown to be in good agreement with diffraction theory. More reasonable results were obtained using these transducers.

A program called PROPRT has been written which prompts the user to enter all of the necessary measured values and then calculates the material properties. It then prints the input and calculated values into a small area which can be cut out and taped onto the box enclosing the measured material. This program is listed in Fig. 5.

Tables of Material Properties

The following tables of material properties are included to aid the reader in the initial screening of materials. Abbreviations are used a great deal to obtain the compact format which is presented. Most abbreviations are explained in a table which follows the table of plastics; however, it is appropriate to at least define the appreviations

```
c       program proprt
c  written by Alan Selfridge 8/12/81
c  This program calculates velocity, impedance, and loss in a material
c  from experimental measurements.
        real loss
        write(1,50)
50      format(' longitudinal wave transit time in microsecs '$
        read(1,100) t
100     format(g0.0)
        write(1,150)
150     format(' amplitude of front face echo in water '$
        read(1,100) a1
        write(1,200)
200     format(' amplitude of backface echo '$
        read(1,100) a2
        write(1,250)
250     format(' weight in air in grams or zero to enter rho '$
        read(1,100) wa
        if(wa.eq.0) go to 320
        write(1,300)
300     format(' weight in water in grams '$
        read(1,100) ww
        rho = wa/(wa - ww)
        go to 340
320     write(1,330)
330     format(' density in g/ml '$
        read(1,100) rho
340     write(1,350)
350     format(' thickness in mils '$
        read(1,100) d
        d = d*0.0254
        vl = 2*d/t
        zl  = rho*vl
        r = (zl - 1.5)/(zl + 1.5)
        r2 = r*r
        loss = -20*alog10(a2/(a1*(1 - r2)))/(d/5)
c  alpha is in db per cm         d/5 = 2*d in cm
        write(1,400)
400     format(' frequency in mhz '$
        read(1,100) freq
        write(1,450) t,vl,a1,rho,a2,zl,wa,freq,ww,loss,d
450     format( '  t=',f6.2,' usecs   vl=',f6.2,' mm/usec',/,
       1        ' a1=',f6.2,' volts  rho=',f6.2,' g/ml    ',/,
       2        ' a2=',f6.2,' volts   zl=',f6.2,' rho*v   ',/,
       3        ' wa=',f6.2,' grams freq=',f6.2,' mhz     ',/,
       4        ' ww=',f6.2,' grams loss=',f6.2,' db/cm   ',/,
       5        '  d=',f6.2,' mm')
        stop
        end
```

Fig. 5. Program PROPRT.

TABLE I
TABLES OF MATERIAL PROPERTIES

	SOLIDS and EPOXIES	VENDOR	V_L	V_S	ρ	Z_L	σ	LOSS
CRC	Aluminum, rolled		6.42	3.04	2.70	17.33	0.355	
	AMD Res-in-all. 502/110, 5:1	AMD	2.67		1.35	3.61		
	AMD Res-in-all. 502/118, 9:1	AMD	2.73		1.35	3.68		
JA	Araldite 502/956	Ciba	2.62		1.16	3.04		
JA	Araldite 502/956, 10phr CSM	Ciba,Li	2.60		1.23	3.19		
JA	Araldite 502/956, 20phr CSM	Ciba,Li	2.54		1.39	3.52		
JA	Araldite 502/956, 30phr CSM	Ciba,Li	2.41		1.58	3.62		
JA	Araldite 502/956, 40phr CSM	Ciba,Li	2.31		1.67	3.86		
JA	Araldite 502/956, 50phr CSM	Ciba,Li	2.13		1.93	4.14		
JA	Araldite 502/956, 60phr CSM	Ciba,Li	2.10		2.24	4.70		
JA	Araldite 502/956, 70phr CSM	Ciba,Li	1.88		3.17	5.95		
JA	Araldite 502/956, 80phr CSM	Ciba,Li	1.72		4.71	8.11		
JA	Araldite 502/956, 50phr 325mesh W	Ciba,Li	2.16		2.86	6.17		
JA	Araldite 502/956, 60phr 325mesh W	Ciba,Li	1.93		2.78	5.33		
JA	Araldite 502/956, 70phr 325mesh W	Ciba,Li	1.82		3.21	5.84		
JA	Araldite 502/956, 80phr 325mesh W	Ciba,Li	1.64		4.55	7.45		
JA	Araldite 502/956, 90phr 325mesh W	Ciba,Li	1.52		8.48	12.81		
AS	Arsenic tri sulphide As2 S3	Ch	2.58	1.40	3.20	8.25	0.29	
M	Bearing babbit		2.30		10.1	23.2		
CRC	Beryllium		12.89	8.88	1.87	24.10	0.046	
	Bismuth		2.2	1.1	9.8	21.5	0.33	
	Boron carbide		11.0		2.4	26.4		

TABLE I (*Continued*)

	SOLIDS and EPOXIES	VENDOR	V_L	V_S	ρ	Z_L	σ	LOSS
	Brass, yellow, 70 Cu, 30 Zn		4.70	2.10	8.64	40.6	0.39	
	Brick		4.3		1.7	7.4		
	Cadmium		2.8	1.5	8.6	24.0	0.30	
AS	Carbon, pyrolytic, soft, variable properties		3.31		2.21	7.31		
AS	Carbon, vitreous very hard material	Fl	4.26	2.68	1.47	6.26	0.17	
	Columbium (see Niobium)							
KF	Concrete		3.1		2.6	8.0		
CRC	Copper, rolled		5.01	2.27	8.93	44.6	0.37	
AS	DER317, 9phr DEH20, 110phr W, r3	C,E	2.18	0.96	2.04	4.45	0.39	6.6 @ 2
AS	DER317, 9phr DEH20, 115phr W, r3	C,E	1.93		2.37	4.58		
AS	DER317, 9phr DEH20, 910phr T1167, r3	C,E	1.50		7.27	10.91		13.2 @ 2
AS	DER317, 10.5phr DEH20 rt, outgass	E	2.75		1.18	3.25		
AS	DER317, 10.5phr DEH20, 110phr W, r3	E,C	2.07		2.23	4.61		8.3 @ 2
AS	DER317, 13.5phr mpda, 50phr W, r1	C,D,E	2.40		1.60	3.84		
AS	DER317, 13.5phr mpda, 100phr W, r1	C,D,E	2.19		2.03	4.44		
AS	DER317, 13.5phr mpda, 250phr W, r1	C,D,E	1.66	0.93	3.4	6.4	0.33	
AS	DER332, 10phr DEH20, rt cure 48 hours	E	2.60		1.20	3.11		
AS	DER332, 10phr DEH20, 120phr alumina, r2	D,E	3.18	1.62	1.76	5.58	0.32	
AS	DER332, 10.5phr DEH20, 10phr alumina, r2	B,E	2.61		1.26	3.29		
AS	DER332, 10.5phr DEH20, 14phr alumina, r2	B,E	2.65		1.29	3.41		
AS	DER332, 10.5phr DEH20, 30phr alumina, r2	B,E	2.75		1.37	3.70		
	DER332, 11phr DEH20, 14phr alumina, r10	B,E	2.71		1.29	3.49		5.4 @ 2
AS	DER332, 11phr DEH20, 150phr alumina, r2	B,E	3.25		1.63	5.95		
AS	DER332,11phr DEH20,250phr alumina,50phr LP3,rt	B,E,T	2.35		1.72	4.05		23.7 @ 2
AS	DER332, 14phr mpda, 30phr LP3, 70C cure	D,E,T	2.59		1.25	3.24		8.3 @ 2
AS	DER332, 25phr mpda, 60C cure	D,E	2.68	1.15	1.21	3.25	0.37	6.7 @ 2
AS	DER332, 15phr mpda, 25phr LP3, 76C cure	D,E,T	2.33	1.10	1.24	3.16	0.36	7.4 @ 1.3
	DER332, 15phr mpda, 30phr LP3, 80C cure	D,E,T	2.66		1.24	3.30		6.8 @ 2
AS	DER332, 15phr mpda, 50phr alumina, 60C cure	B,D,E	2.8	1.43	1.49	4.18	0.32	
AS	DER332, 15phr mpda, 60phr alumina, 80C cure	B,D,E	2.78	1.45	1.54	4.27	0.31	
AS	DER332, 15phr mpda, SiC, r5	C,D,E	3.90		2.24	8.74		
AS	DER332, 15phr mpda, SiC, 25phr LP3, r5	C,D,E,T	3.75		2.15	8.06		
AS	DER332, 15phr mpda, 6 micron W, r5	C,D,E	1.75		6.45	11.3		
AS	DER332, 50phr V140, rt cure	E,GM	2.34	0.97	1.13	2.64	0.40	
AS	DER332, 64phr V140, rt cure	E,GM	2.36		1.13	2.65		
AS	DER332, 75phr V140, rt cure	E,GM	2.35		1.12	2.62		
AS	DER332, 100phr V140, rt cure	E,GM	2.32		1.10	2.55		
AS	DER332, 100phr V140, 30phr LP3, r8	E,GM,T	2.27		1.13	2.55		7.5 @ 2, 11.2 @ 2.5
AS	DER332, 100phr V140, 30phr LP3, r9	E,GM,T	2.36		1.16	2.74		9.6 @ 2
AS	DER332, 100phr V140, 50phr LP3, r8	E,GM,T	2.32		1.13	2.63		12.0 @ 2
AS	DER332, 50phr V140, 50phr St. Helens ash, 60C	E,GM,?	2.43		1.94	6.21		
CRC	Duraluminum 17S		6.32	3.13	2.79	17.63	0.34	
AS	Duxseal	JM	1.49		1.68	2.50		13.3 @ 0.5
AS	Epoxy glue, EPX-1 or EPX-2, 100phA of B	Loc	2.44		1.10	2.68		8.4 @ 5
	Epon 826, mpda	Sh,D	2.820	1.23	1.21	3.4	0.45	
	Epotek 301	Ha	2.64		1.08	2.85		
	Epotek 330	Ha	2.57		1.14	2.94		
	Epotek H70S	Ha	2.91		1.68	4.88		
AS	Epotek V6, 100phA of B, r6	Ha	2.61		1.23	3.21		4.5 @ 2
AS	Epotek V6, 100phA of B, r7	Ha	2.55		1.23	3.14		8 @ 2
AS	Epotek V6, 100phA of B, 20phA LP3, r6	Ha,T	2.60		1.25	3.25		6 @ 2
AS	Epotek V6, 100phA of B, 20phA LP3, r7	Ha,T	2.55		1.26	3.22		6 @ 2
	Fused silica	Dyna	5.96	3.76	2.20	13.1	0.17	6.2e-3 @ 2
M	Germanium, mp=937.4C, transparent to infrared	C	5.41		5.47	29.6		
	Glass, corning 0215 sheet	Corn	5.66		2.49	14.09		
	Glass, crown	RG	5.1	2.8	2.24	11.4	0.28	
	Glass, FK3	Schott	4.91	2.85	2.26	11.1	0.245	
	Glass, FK6 large minimum order	Schott	4.43	2.54	2.28	10.1	0.23	
AE	Glass, flint		4.5		3.6	16.0		
	Glass, macor machinable code 9658	Lee	5.31		2.54	14.0		
	Glass, pyrex	Corn	5.64	3.28	2.24	13.1	0.24	
AE	Glass, quartz		5.5		2.2	12.		
AE	Glass, silica		5.9		2.2	13.0		
	Glass, soda lime		6.00		2.24	13.4		
	Glass, FIR	Schott	4.38		2.38	10.5		
RB	Glucose		3.20		1.56	5.0		
CRC	Gold, hard drawn		3.24	1.20	19.7	63.8	0.42	
AH	Granite		6.5		4.1	26.8		
M	Hafnium, mp=2150C, used in reactor control rods	C	3.84		13.29	51.0		

TABLE I (*Continued*)

	SOLIDS and EPOXIES	VENDOR	V_L	V_S	ρ	Z_L	σ	LOSS
	Hydrogen, solid at 4.2K		2.19		0.039	0.19		
	Hysol ES 4212, 1:1	H	2.32		1.50	3.49		
	Hysol ES 4412, 1:1	H	2.02		1.60	3.30		
ES	Hysol C8-4143/3404	H	2.85		1.58	4.52		
BB	Hysol C9-4183/3561	H	2.92		1.48	4.3		
BB	Hysol C9-4183/3561, 15phe CSW	H,Li	2.62		1.80	4.7		
BB	Hysol C9-4183/3561, 30phe CSW	H,Li	2.49		2.14	5.33		
BB	Hysol C9-4183/3561, 45phe CSW	H,Li	2.30		2.66	6.10		
BB	Hysol C9-4183/3561, 57.5phe CSW	H,Li	2.16		3.27	7.04		
BB	Hysol R8-2038/3404	H	2.59		1.18	3.05		
BB	Hysol R9-2039/3404	H	2.59		1.13	2.92		
BB	Hysol R9-2039/3469	H	2.61		1.17	3.07		
ER	Hysol R9-2039/3561	H	2.53		1.18	3.0		
	Inconel		5.7	3.0	8.28	47.2	0.31	
	Indium	I	2.56		7.3	18.7		
	Iron		5.9	3.2	7.69	46.4	0.29	
	Iron, cast		4.6	2.6	7.22	33.2	0.27	
	Lead		2.2	0.7	11.2	24.6	0.44	
	Lead metaniobate	Kera	3.30		6.2	20.5		q=15
	Lithium niobate, 36 rot. Y-cut	CT	7.08		4.7	33.0		
	Magnesium, various types listed in ref 'M'		5.8	3.0	1.738	10.0	0.32	
AE	Marble		3.8		2.8	10.5		
AS	MF-190	EC	2.67		4.45	11.88		15.9 @ 4.0
	Molybdenum		6.3	3.4	10.0	63.1	0.29	
	Monel		5.4	2.7	8.82	47.6	0.33	
AS	Murata PZT	Mura	4.72		7.95	37.5		
	Nickel		5.6	3.0	8.84	49.5	0.30	
M	Niobium, m.p.= 2468C	C	4.92	2.10	8.57	42.2	0.39	
AE	Paraffin		1.5		1.5	2.3		
CRC	Platinum		3.26	1.73	21.4	69.8	0.32	
	Polyester casting resin	Tap	2.29		1.07	2.86		
AE	Porcelain		5.9		2.3	13.5		
	PSN, potassium sodium niobate		6.94		4.46	31.0		
	Pressed graphite		2.4		1.8	4.1		
	PZT 5H, Vernitron	EBL	4.44		7.43	33.0		
	PVF2	3m	2.30		1.79	4.2		q=10
AF	Quartz, X-cut	VF	5.75	2.2	2.65	15.3	0.42	
M	Rubidium, mp=38.9, a 'getter' in vacuum tubes	C	1.26		1.53	1.93		
M	Salt, NaCl, crystalline, X direction		4.78		2.17	10.37		
	Sapphire, aluminum oxide, Z axis		11.15		3.98	44.46		
DP	Scotch tape 2.5 mils thick	3m	1.9		1.16	2.09		
AS	Scotchcast XR5235, 30phA B, rt cure	3m	2.40		1.49	3.78		3.0 @ 1.3
	Scotchply SP1002, a laminate with fibers	3m	3.25		1.94	6.24		
	Scotchply XP 241	3m	2.84		0.65	1.84		
AS	Silicon, very anisotropic, values are approx.		8.43	5.84	2.34	19.7		
	Silicon carbide		6.66		13.8	91.8		
	Silicon nitride		11.0	6.25	3.27	36.0	0.28	
	Silver		3.6	1.6	10.6	38.0	0.38	
AS	Silver epoxy, e-solder 3022	Acme	1.9	0.98	2.71	5.14	0.32	16 @ 2
AE	Slate		4.5		3.0	13.5		
	Steel, mild		5.9	3.2	7.80	46.0	0.29	
	Steel, stainless 347, Zs = 24.5		5.79	3.10	7.89	45.7	0.30	
	Stycast 1264, rt cure	EC	2.22		1.19	2.64		
	Stycast 1267	EC	2.57		1.16	3.00		4.6 @ 3.0
JA	Stycast 1970, costs $109.00/lb	EC	3.2		1.90	6.08		
AS	Stycast 2651-40 9phr cat9 rt cure	EC	2.77		1.5	4.16		
AS	Stycast 2651-40 9phr cat9, 10phr SiC	EC,C	2.88		1.37	4.53		
AS	Stycast 2651-40 9phr cat9, 20phr SiC	EC,C	2.95		1.63	4.82		
AS	Stycast 2651-40 9phr cat9, 25phr SiC	EC,C	2.90	1.50	1.67	4.85	0.32	
	Stycast 2741, 1:1	EC	2.29		1.17	2.68		
M	Sulphur, 9 isotropic forms exist, mp approx 112C		1.35		2.0	2.7		
M	Tantalum, mp=2996C, very inert, hard	C	4.10	2.90	16.6	54.0		
M	Thorium, mp=1783C, fissionable, high melting oxide		2.40	1.56	11.3	33.2	0.134	
AS	Tapox epoxy	Tap	2.40		1.11	2.76		
AS	Techform EA700, brittle material	Tech	2.63		1.20	3.14		4.6 @ 2, 5.2 @ 2.5
	Teflon		1.39		2.14	2.97		3.9 @ 5
	Tin		3.3	1.7	7.3	24.2	0.31	
	Titanium, mp=1725C		6.1	3.1	4.48	27.3	0.32	

TABLE 1 (*Continued*)

	SOLIDS and EPOXIES	VENDOR	V_L	V_S	ρ	Z_L	σ	LOSS
M	Titanium carbide, mp=3140C	C	8.27	5.16	5.15	42.6		
	Tracon 401 ST	Tr	2.97		1.62	4.82		
	Tracon 2135 D	Tr	2.45		1.03	2.52		
	Tracon 2143 D	Tr	2.37		1.05	2.50		
	Tracon 2162 C	Tr	2.02		1.19	2.41		
	Tracon 3011	Tr	2.12		1.2	2.54		
	Tungsten	C	5.2	2.9	19.4	101.0	0.27	
	Unobtainium	proprietary						
	Uranium	C	3.4	2.0	18.5	63.0	0.24	
M	Uranium dioxide	C	5.18		10.96	56.7		
M	Vanadium, mp=1890C	C	6.00	2.78	6.03	36.2	0.36	
KF	Wood, cork		0.5		0.24	0.12		
KF	Wood, oak		4.0		0.72	2.9		
KF	Wood, pine		3.5		0.45	1.57		
	Zinc, often ver, granular		4.2	2.4	7.0	29.6	0.26	
	Zinc oxide		6.40	2.95	5.68	36.4	0.37	
M	Zircaloy		4.72	2.36	9.36	44.2		
M	Zirconium, mp=1852C, used in poison ivy lotion	C	4.65	2.25	6.49	30.1	0.35	

	PLASTICS	VENDOR	V_L	V_S	ρ	Z_L	σ	LOSS
AS	ABS, Beige	Port	2.23		1.03	2.31		11.105
AS	ABS, Black, Injection molded Grade 7, Color #4500, "Cycolac"	Borg	2.25		1.05	2.36		10.905
AS	ABS, Grey, Injection molded Grade T, Color #GSM 32627	Borg	2.17		1.07	2.32		11.305
AS	Acrylic, Clear, Plexiglas G Safety Glazing	Rohm	2.75		1.19	3.26	0.40	6.405
AS	Acrylic, Plexiglas MI-7	Rohm	2.61		1.18	3.08	0.40	12.405
M	Bakelite	UC	1.59		1.40	3.63		
AS	Cellulose Butyrate		2.14		1.19	2.56		21.905
AS	Delrin, Black	D	2.43		1.42	3.45		30.305
JA	Ethyl vinyl acetate, VE-630 (18% Acetate)	USI	1.80		0.94	1.69		
JA	Ethyl vinyl acetate, VE-634 (28% Acetate)	USI	1.68		0.95	1.60		
JA	Kydex, PVC Acrylic Alloy Sheet	Rohm	2.210		1.35	2.99		
AS	Lexan, Polycarbonate	GEP	2.30		1.20	2.75		23.205
AS	Lustran, SAN	Mons	2.51		1.06	2.68		5.105
	Mylar	D	2.54		1.18	3.00		
AS	Kodar PETG, 6763, Copolyester	Kodak	2.34		1.27	2.97		20.005
	Nelcpas	AMPL	2.90		1.7	4.93		7.202.5
	Nylon, 6/6		2.6	1.1	1.12	2.9	0.39	2.985
AS	Nylon, Black, 6/6	Port	2.77		1.14	3.15		16.005
AS	Polycarbonate, Black, Injection molded Grade 141R, Color No. 701, 'Lexan'	GEP	2.27		1.22	2.77		22.105
AS	Polycarbonate, Blue, Injection molded Grade M-40, Color No. 8867, 'Merlon'	Mobay	2.26		1.20	2.72		23.305
AS	Polycarbonate, Clear, Sheet Material	Port	2.27		1.18	2.69		24.905
CRC	Polyethylene		1.95	0.54	0.90	1.76		
	Polyethylene, high density, LB-861	USI	2.43		0.96	2.33		
	Polyethylene, low density, NA-117	USI	1.95	0.54	0.92	1.79	0.46	2.405
	Polyethylene oxide, WSR 301	UC	2.25		1.21	2.72		
	Polypropylene, Profax 6432, Hercules	USI	2.74		0.88	2.40		5.105
AS	Polypropylene, White, Sheet Material	Port	2.66		0.89	2.36		18.205
	Polystyrene, "Fostarene 50"	Amer	2.45		1.04			
AS	Polystyrene, "Lustrex", Injection molded Resin #HF55-2020-347	Mons	2.32		1.04	2.42		3.605
	Polystyrene, Styron 666	E	2.40	1.15	1.05	2.52	0.35	1.805
	Polyvinyl butyral, Butacite, used to laminate safety glass together	D	2.35		1.11	2.60	0.37	
	P50, Polysulfone	UC	2.24		1.24	2.76		4.2502
AS	PVC, Grey, Rod Stock, Normal Impact Grade	Port	2.38		1.38	3.27		11.205
AS	Styrene Butadiene, KR 05 NW	Phil	1.97		1.02	1.95		24.305
AS	TPX-DX845, Dimethyl pentene polymer	MP	2.22		0.83	1.84		3.001.3,4,404
AS	Valox, Black, (glass filled nylon)	GE	2.53		1.52	3.83		15.705
AS	Vinyl, Rigid		2.23		1.33	2.96		12.805

RUBBERS	VENDOR	V_L	ρ	Z_L	LOSS
Adiprene LW-520	Uni	1.68	1.16	1.94	
Butyl rubber		1.80	1.11	2.0	

TABLE I (*Continued*)

	RUBBERS	VENDOR	V_L	ρ	Z_L	LOSS
AS	Dow Silastic Rubber 6P45, 45 Durometer	NPC	1.02	1.14	1.16	23.404
AS	Dow Silastic Rubber 6P70, 70 Durometer	NPC	1.04	1.25	1.30	33.704
AS	Ecogel 1265, 100PHA OF B, octgass, BBC	EC	1.96	1.10	2.16	33.402
AS	Ecogel 1265, 100PHA OF B, 100PHA Alumina, R4	EC,P	1.70	1.40	2.33	>24,001.3
AS	Ecogel 1265, 100PHA OF B, 1940PHA T1167, R4	EC,C	1.32	9.19	12.16	1400.4
	Ecothane CPC-39	EC	1.53	1.06	1.63	
	Ecothane CPC-41	EC	1.52	1.01	1.54	
	Neoprene		1.6	1.31	2.1	
AS	Fellathane, Thermoplastic Urethane Rubber 550 durometer	Uoj	2.10	1.20	2.62	32.005
AS	Polyurethane, SC1090	Ball	1.76	1.11	1.96	46.104
BB	Polyurethane, RP-6400	REN	1.50	1.04	1.56	
BB	Polyurethane, RP-6401	REN	1.63	1.07	1.74	
BB	Polyurethane, RP-6402	REN	1.77	1.03	1.91	
BB	Polyurethane, RP-6403	REN	1.87	1.10	2.05	
BB	Polyurethane, RP-6405	REN	2.09	1.30	2.34	
BB	Polyurethane, RP-6410	REN	1.33	1.04	1.38	
BB	Polyurethane, RP-6413	REN	1.65	1.04	1.71	
BB	Polyurethane, RP-6414	REN	1.78	1.05	1.86	
BB	Polyurethane, RP-6422	REN	1.60	1.04	1.66	
AS	PR-1201-Q (MEDIUM), PHR 10, RT Cure	PRC	1.45	1.79	2.59	12.202
	RTV-11	GE,RS	1.05	1.19	1.24	2.500.8
	RTV-21	GE,RS	1.01	1.31	1.32	2.600.8
	RTV-30	GE	0.97	1.45	1.41	2.800.8
	RTV-41	GE,RS	1.01	1.31	1.32	3.200.8
	RTV-60	GE,RS	0.96	1.47	1.41	2.800.8
	RTV-77	GE	1.02	1.33	1.36	3.200.8
	RTV-90	GE	0.96	1.5	1.44	4.200.8
	RTV-112	GE,RS	0.94	1.05	0.99	
	RTV-116	GE,RS	1.02	1.10	1.12	
	RTV-118	GE,RS	1.03	1.04	1.07	
	RTV-511	GE,RS	1.11	1.16	1.31	2.500.8
AS	RTV-560	GE,RS	0.99	1.41	1.40	2.200.8,6.402
	RTV-577	GE,RS	1.06	1.35	1.46	3.000.8
	RTV-602	GE	1.16	1.02	1.18	4.3500.8
	RTV-615, use with 4155 primer	GE,RS	1.09	1.02	1.10	103.8
	RTV-616	GE,RS	1.06	1.22	1.29	2.200.8
	RTV-630	GE,RS	1.05	1.24	1.32	
JF	Silly Putty, very lossy, hard to measure		1.0	1.2	1.9	
JA	Sylgard 170, a silicon rubber		0.974	1.38	1.34	
JA	Sylgard 182	E	1.027	1.05	1.07	
JA	Sylgard 184	E	1.027	1.05	1.04	
JA	Sylgard 186	E	1.027	1.12	1.15	

	LIQUIDS	VENDOR	V_L	$\Delta V/\Delta T$	ρ	Z_L	LOSS
M	Acetate, butyl		1.27		0.871	1.02	
M	Acetate, ethyl, C4H8O2		1.19		0.900	1.069	
M	Acetate, methyl, C3H6O2		1.21		0.934	1.131	
M	Acetate, propyl		1.18		0.891	1.05	
LB	Acetone, (CH3)2cCO at 25C		1.174	-4.5	0.791	1.07	A=54.0
M	Acetonitrile, C2H3N		1.29		0.783	1.01	
M	Acetonyl acetone, C6H10O2		1.40		0.729	1.359	
M	Acetylendichloride, C2H2Cl2		1.02		1.26	1.280	
M	Alcohol, butyl, C4H9OH at 30C		1.24		0.610	1.003	A=74.3
CRC	Alcohol, ethanol, C2H5OH, at 25C		1.207	-4.0	0.79	0.95	A=48.5
M	Alcohol, furfuryl, C5H4O2		1.45		1.135	1.645	
LB	Alcohol, isopropyl, 2-Propanol, at 20C		1.17		0.786	0.920	A=92
CRC	Alcohol, methanol, CH3OH, at 25C		1.103	-3.2	0.791	0.872	A=30.2
M	Alcohol, propyl (n) C3H7OH at 30C		1.22		0.804	0.983	A=64.5
M	Alcohol, t-amyl, C5H9OH		1.20		0.810	0.976	
M	Alkazene 13, C15H24		1.32		0.860	1.132	
M	Analine, C6H5NH2		1.69		1.022	1.675	
DR	Argon, liquid at 87K		0.040		1.43	1.20	A=15.2
CRC	Benzene, C6H6, at 25C		1.295	-4.65	0.87	1.12	A=873
M	Benzol		1.33		0.878	1.16	
M	Benzol, ethyl		1.34		0.868	1.16	
	Bromobenzene C6H5Br at 22C		1.167		1.522	1.776	A=1.63
M	Bromoform, CHBr3		0.92		2.890	2.670	

TABLE I (*Continued*)

	LIQUIDS	VENDOR	v_L	dv/dT	ρ	Z_L	LOSS
M	t-Butyl chloride, C4H9Cl		0.98		0.84	0.827	
M	Butyrate, ethyl		1.17		0.877	1.03	
M	Carbitol, C6H14O3		1.46		0.988	1.431	
CRC,M	Carbon disulphide, CS2 at 25C		1.149		1.26	1.448	
DR	Carbon disulphide, CS2, 25C, 3 GHz		1.310		1.221	1.65	A=10.1
CRC,M	Carbon tetrachloride, C(Cl)4, at 25C		0.926	-2.7	1.594	1.48	A=538
M	Cesium at 28.5C the melting point	C	0.967		1.88	1.82	
LB	Chloro-benzene, C6H5Cl, at 22C		1.304		1.106	1.442	A=167
M	Chloro-benzene, C6H5C		1.30		1.10	1.432	
CRC,M	Chloroform, CHCl3, at 25C		0.987	-3.4	1.49	1.47	
M	Cyclohexanol, C6H12O		1.45		0.962	1.48	
M	Cyclohexanone, C6H10O		1.42		0.948	1.391	
M	Diacetyl, C4H6O2		1.24		0.99	1.222	
M	Dichloroisobutane (1.3), C4H10(Cl)2		1.22		1.14	1.390	
M	Diethyl ketone		1.31		0.813	1.07	
M	Dimethyl phthalate, C8H10O4		1.46		1.20	1.750	
M	Dioxane		1.38		1.033	1.425	
CRC,M	Ethanol amide, C2H7NO, at 25C		1.724	-3.4	1.018	1.755	
CRC,M	Ethyl ether, C4H10O, at 25C		0.985	-4.87	0.713	0.7023	
M	d-Fenchone		1.32		0.94	1.241	
M	Florosilicone oil, Dow FS-1265		0.76				
M	Formamide, CH3NO		1.62		1.134	1.842	
M	Furfural, C5H4O2		1.45		1.157	1.670	
3m	Fluorinert FC-40	3m	0.640		1.86	1.19	
3m	Fluorinert FC-70	3m	0.687		1.94	1.33	
3m	Fluorinert FC-72	3m	0.512		1.68	0.86	
3m	Fluorinert FC-75	3m	0.585		1.76	1.02	
3m	Fluorinert FC-77	3m	0.595		1.78	1.05	
3m	Fluorinert FC-104	3m	0.575		1.76	1.01	
3m	Fluorinert FC-43	3m	0.655		1.85	1.21	
LB	Fluoro-benzene, C6H5F, at 22C		1.18		1.024	1.205	A=317
AS	Freon, TF	VWR	0.716		1.57	1.12	
DR	Gallium at 30C mp=29.8 expands 3% when it freezes		2.87		6.09	17.5	A=1.58
M	Gasoline		1.25		0.803	1.00	
CRC	Glycerin, CH2OHCHOHCH2OH, at 25C		1.904	-2.2	1.26	2.340	
M	Glycol, butylene (2,3)		1.48		1.019	1.511	
M	Glycol, diethylene, C4H10O3		1.58		1.116	1.770	
CRC	Glycol, ethylene, 1,2-ethanediol, at 25C		1.658	-2.1	1.113	1.845	A=120
JA	Glycol, ethylene, Preston II	Preston	1.59		1.100	1.76	
JA	Glycol, polyethylene 200	SW	1.62		1.087	1.75	
JA	Glycol, polyethylene 400	SW	1.62		1.06	1.71	
M	Glycol, polypropylene (Polyglycol P-400) at 30C		1.30				
M	Glycol, polypropylene (Polyglycol P-1200) at 30C		1.30				
M	Glycol, polypropylene (Polyglycol E-200) at 29C		1.57				
M	Glycol, tetraethylene, C8H18O6		1.58		1.12	1.784	
M	Glycol, triethylene, C6H14O4		1.61		1.123	1.81	
DR	Helium-4, liquid at 0.4K		0.238		0.147	0.035	A=1.73
DR	Helium-4, liquid at 2K		0.227		0.145	0.033	A=70
DR	Helium-4, liquid at 4.2K		0.183		0.126	0.023	A=226
	n-Hexane, C6H14, liquid at 30C		1.103		0.659	0.727	A=87
M	n-Hexanol, C6H14O		1.30		0.819	1.065	
AS	Honey, sue bee orange		2.03		1.42	2.89	
	Hydrogen, liquid at 20K		1.19		0.07	0.08	A=5.6
LB	Iodo-benzene, C6H5I, at 22C		1.104		1.183	2.012	A=242
M	Isopentane, C5H12		0.992		0.62	0.615	
CRC,M	Kerosene		1.324	-3.6	0.81	1.072	
M	Linalool		1.40		0.884	1.23	
CRC	Mercury at 25.0C		1.450		13.5	19.58	A=5.8
M	Mesityloxide, C6H10O		1.31		0.85	1.115	
M	Methylethylketone		1.21		0.805	0.972	
M	Methylene iodide		0.98				
M	Methyl napthalene, C11H10		1.51		1.090	1.645	
M	Monochlorobenzene, C6H5Cl		1.27		1.107	1.411	
M	Morpholine, C4H9NO		1.44		1.00	1.442	
DR	Neon, liquid at 27K		0.600		1.20	0.72	A=23.1
LB	Nicotin, C10H14N2, at 20C		1.49		1.01	1.505	
CRC,M	Nitrobenzene, C6H5NO2, at 25C		1.463	-3.6	1.20	1.756	
DR	Nitrogen, N2, liquid at 77K		0.860		0.80	0.68	A=13.8
M	Nitromethane, CH3NO2		1.33		1.13	1.504	

TABLE I (*Continued*)

	LIQUIDS	VENDOR	V_L	$\Delta V/\Delta T$	ρ	Z_L	LOSS
JA	Oil, baby	J&J	1.43		0.821	1.17	
CRC,M	Oil, castor, C11H10O10 @ 25C		1.477	-3.6	0.969	1.431	
SD	Oil, castor, @ 20.2C @ 4.224 MHz		1.507		0.942	1.420	A=18100.
JA	Oil, corn	Mazola	1.46		0.922	1.34	
M	Oil, diesel		1.25				
M	Oil, gravity fuel AA		1.49		0.99	1.472	
JA	Oil, linseed		1.46		0.94	1.37	
M	Oil, linseed		1.77		0.922	1.63	
JA	Oil, mineral, light	Diamond	1.44		0.825	1.19	
JA	Oil, mineral, heavy	Diamond	1.46		0.843	1.23	
JA	Oil, olive		1.445		0.918	1.32	
M	Oil, parrafin		1.42		0.835	1.86	
JA	Oil, peanut	Planter	1.436		0.914	1.31	
M	Oil, SAE 20		1.74		0.870	1.51	
	Oil, SAE 30		1.7		0.88	1.5	
JA	Oil, silicon Dow 200, 1 centistoke	DC	0.96		0.818	0.74	
JA	Oil, silicon Dow 200, 10 centistoke	DC	0.968		0.940	0.91	
JA	Oil, silicon Dow 200, 100 centistoke	DC	0.98		0.968	0.95	
JA	Oil, silicon Dow 200, 1000 centistoke	DC	0.99		0.972	0.96	
ED	Oil, silicon Dow 710 @ 20C	DC	1.352		1.11	1.50	A=6200.
JA	Oil, safflower		1.45		0.90	1.30	
JA	Oil, soybean	Wesson	1.43		0.93	1.32	
M	Oil, sperm		1.44		0.88	1.268	
JA	Oil, sunflower		1.45		0.92	1.34	
M	Oil, transformer		1.39		0.92	1.28	
JA	Oil, wintergreen (methyl salicylate)	CVS	1.38		1.16	1.60	
DR	Oxygen, O2, liquid at 90K		0.900		1.11	1.0	A=9.9
M	Paraffin at 15C		1.30				
	n-Pentane, C5H12, liquid at 15C		1.027		0.626	0.642	A=100
M	Polypropylene oxide (Aubiflo) at 38C		1.37				
M	Potassium at 100C, mp=63.7C see 'M' for other temps)		1.82		0.83	1.51	
M	Pyridine		1.41		0.982	1.39	
M	Sodium, liquid at 300C, (see 'M' for other temps)		2.42		0.81	21.32	
M	Solvesso 03		1.37		0.877	1.202	
AS	Sonotrack couplant	Echo	1.62		1.04	1.68	
M	Tallow at 16C		0.39				
M	Thallium at mp=303.5c, used in photocells	C	1.62		11.9	19.3	
M	Trichorethylene		1.05		1.05	1.10	
CRC	Turpentine, at 25C		1.255		0.88	1.104	
M	Univis 800		1.35		0.87	1.191	
M	Water, heavy, D20		1.40		1.104	1.54	
M	Water, liquid at 20C		1.48		1.00	1.483	
CRC,DR	Water, liquid at 25C		1.4967	2.4	0.998	1.494	A=22
	Water, liquid at 30C		1.509		1.00	1.509	A=19.1
DR	Water, liquid at 60C, temps up to 500F listed in 'CRC'		1.55		1.00	1.55	A=10.9
M	Water, salt 10%		1.47				
M	Water, salt 15%		1.53				
M	Water, salt 20%		1.60				
CRC	Water, sea, at 25C		1.531	2.4	1.023	1.569	
DR	Xenon, liquid at 166K		0.630		2.86	1.80	A=22.0
CRC,M	Xylene Hexaflоride, C8H4F6, at 25C		0.879		1.37	1.222	
M	o-Xylol, C8H10		1.32		0.864	1.145	

	GASES	VENDOR	V	$\Delta V/\Delta T$	$\rho * 10^3$	$Z * 10^3$	LOSS
CRC	Acetone vapor, C3H6O at 97.1C		0.239	0.32			
CRC	Air, dry at 0C		0.33145	0.59	1.293	0.4286	
M	Air, at 0C, 73 atm		0.332				
M	Air at 0C, 50 atm		0.335				
M	Air at 0C, 100 atm		0.351				
M	Air at 20C		0.344				
M	Air at 100C		0.386				
M	Air at 500C		0.553				
CRC	Ammonia, NH3 at 0C		0.415		0.771	0.320	
CRC	Argon at 0C		0.319	0.56	1.783	0.569	
CRC	Benzene vapor, C6H6 at 97.1C		0.202	0.3			
CRC	Carbon monoxide, CO at 0C		0.338	0.6	1.25	0.423	
CRC	Carbon dioxide, CO2 at 0C		0.259	0.4	1.977	0.512	

TABLE I (*Continued*)

	GASES	VENDOR	V	[illegible]	ρ×10³	Z×10³	LOSS
M	Carbon disulfide		0.189				
CRC	Carbon tetrachloride vapor, C(Cl)4 at 97.1C		0.145				
CRC	Chlorine at 0C		0.205		3.214	0.662	
CRC	Chloroform, CH(Cl)3 at 97.1C		0.171	0.24			
CRC	Deuterium at 0C		0.890	1.6	0.19	0.1691	
CRC	Ethane, C2H6 at 0C		0.308		1.356	0.418	
CRC	Ethylene, C2H4 at 0C		0.317		1.260	0.400	
CRC	Ethanol vapor, C2H5OH at 97.1C		0.269	0.4			
CRC	Ethyl ether, C4H10O at 97.1C		0.205	0.3			
CRC	Helium at 0C		0.965	0.8	0.178	0.172	
CRC	Hydrogen at 0C		1.284	2.2	0.0899	0.1154	
CRC	Hydrogen bromide, HBr at 0C		0.200		3.50	0.700	
CRC	Hydrogen chloride, HCl at 0C		0.296		1.639	0.485	
CRC	Hydrogen iodide, HI at 0C		0.157		5.66	0.889	
CRC	Hydrogen sulfide, H2S at 0C		0.289		1.539	0.445	
CRC	Methane, CH4 at 0C		0.430		0.7168	0.308	
CRC	Methanol vapor, CH3OH at 97.1C		0.335	0.46			
CRC	Neon, at 0C		0.435		0.900	0.392	
CRC	Nitric oxide, NO at 10C		0.324		1.34	0.434	
CRC	Nitrogen, N2 at 0C		0.334	0.6	1.251	0.418	
CRC	Nitrous oxide, N2O at 0C		0.263	0.5	1.977	0.520	
CRC	Oxygen, O2 at 0C		0.316	0.56	1.429	0.451	
M	Oxygen, O2 at 20C		0.328		1.32	0.433	
CRC	Sulfur dioxide, SO2 at 0C		0.213	0.47	2.927	0.623	
M	Water vapor at 0C		0.401				
M	Water vapor at 100C		0.405				
CRC	Water vapor at 134C		0.494				

<u>VENDOR ABBREVIATIONS</u>

3a	Bay Area, (415)257-2244, Los Angeles, (213)726-6305
Acme	Acme Chemicals, PO Box 1404, New Haven, Conn. 06505, (203)562-2171
AMD	AMD Engineering, Rockland, Ma. 02370
Amer	American Hoechst Corp., Tustin, Ca. (714)730-5851
AMPL	AMPL Prochal, Paris, France
B	Brinkman Instruments Inc., Great Neck L.I.N.Y.
	Chemistry Stores, Stanford University, Stanford Ca. 94305, (414)497-1277
Borg	Borg-Warner Chemicals Inc., International Center, Parkersburg, W. Va. 26101 (304)424-5411
	Colorite Plastics Co., 101 Railroad Ave., Richfield N.J. 07657
C	Cerac, PO Box 1178, Milwaukee, Wis. 53201, (414)289-9800
Ch	Chemtel, Hayward, Ca., (415)785-0330
Ciba	Ciba-Araldite Products
Corn	Corning Glass Works, S. Taaffe, Sunnyvale, Ca., (408)732-5850
	Corning Glass, Corning, N.Y.
CVS	Local pharmacy
D	E.I. Dupont de Nemours, N8533 Freon Products Div., Wilmington, Del. 19898 (800)441-7515
	Ventron Corp., Alpha Products, 2098 Pine St., San Leandro, Ca. 94577
	Ventron Corp., Alpha Division, Danver, Mass., (617)777-1970x486
DC	Dow Corning, (everything is silicon based) Fresno, Ca. (209)4418201
	K. R. Anderson, 136 Wolfe Rd., Sunnyvale, Ca. 94086 (408)734-6730
	Bronell Electro Products (212)924-5800
Dyna	Dynasil Corp., Cooper Rd., Berlin, N.J. 08009 (609)767-4600 Marty Sarpoff
E	E. T. Horn Co., 541 66th Ave., Oakland, Ca. 94621, (415)568-2737
	Dow Chemical
EBL	EBL, 91 Tolland St., East Hartford, Conn. 06108, (203)289-5428
	Vernitron, 232 Forbes Rd., Bedford, Ohio 44146, (216)232-8600
	Wolfe Engineering, (714)646-7214
	Channel Industries, 839 Ward Dr., Santa Barbara, Ca. 93105, (805)967-0171
	Transducer Products, Rt 63 North, Goshen, Conn., (203)491-3251
Echo	Echo Labs, PO Box 552, Lewiston, Penn. 17044, (717)248-4993
EC	Emerson Cumings, 604 W 182nd St., Gardena, Ca. 90248, (213)329-1147, (213)321-6650x33
Fl	Flourocarbon Process Systems, 1432 S Allec St., PO Box 3640; Anaheim, Ca. 92803, (714)956-7330
Gall	Gallagher Corp., 3966 Morrison Dr., Gurnee, Ill. 60031 (312)249-3440 Richard Gallagher
GE	General Electric, Silicon Products, Waterford, N.Y. 12188, (518)237-3330
	Electrical Specialty Co., 213 E. Harris Ave., So. San Francisco, Ca. (415)589-9611
GEP	General Electric, 1700 E. Bale, City of Industry, Ca. 91745
GR	E.V. Roberts and Associates, Palo Alto, Ca., (415)494-1671
	E.V. Roberts and Associates, 8500 Stellar Dr., Culver City, Ca. 90230

TABLE I (*Continued*)

	Henkel Corporation
	General Mills
H	Hysol Division, Dexter Corp., Olean, N.Y. 14760
	Hysol Insulating Materials, 15051 E. Don Julian Rd., Industry, Ca. 91749, (213)968-6511 (415)687-4201
I	Indium Corp., PO Box 269, Utica, N.Y. 13503, (317)797-1630 Telex 937363
JM	Johns-Manville
	Electrical Materials Inc., San Antonio Rd., Palo Alto, Ca. (415)494-0420
Kera	Keramos Inc., 104 N. Church, Lizton, Ind. 46149
Kodak	Eastman Chemical Products Inc., Kingsport, Tenn.
Lee	Lee Plastics, 795 E. Pico Blvd., Los Angeles, Ca. 90021, (213)746-5904
Li	Li Tungsten Co., 63 Herbhill Rd., Glencove, N.Y. 11542, (516)676-1314
Loc	Koblick Supply, 2950 Bay Rd., Redwood City, Ca. 94063, (415)364-7330
	Loctite, 18731 Cranwood Parkway, Cleveland, Ohio 44128, (800)321-9100,09
MPC	Medical Products Corp., PO 1274, Racine, Wisc. 53405, (414)634-1556
Mobay	Mobay Chemical Corp., 16661 Von Karman Ave., Irvine, Ca. 92714
Mons	Monsanto Co. 800 N. Lindbergh Blvd., St. Louis, Mo. 63166 (314)694-1000
Mura	Murata Corp. of America, 1148 Franklin Rd. S.E., Marietta, Ga. 30067, (404)952-9777 Jiro Miyazaki
Phil	Phillips Petroleum
Port	Port Plastics, 1047 W. Fairoaks Ave., Sunnyvale, Ca 94086 (415)324-1391, (408)744-1111
PRC	Products Research and Chemical Corp., 5430 San Fernando, Glendale Ca. 91203
Ren	Ren Plastics, Div. of Ciba Geigy, 18424 Mt Langley, Fountain Valley, Ca., (714)963-8704
RG	Royal Glass, 450 Cambridge Ave., Palo Alto, Ca., (415)321-5510
Rohm	Rohm and Haas
RS	R. S. Hughes Co., 1162 Sonora Court, PO Box 515, Sunnyvale, Ca. 94086 (407)739-3211
	Electrical Specialties Co. (415)539-9611
Schott	Schott Optical Glass, PO Box 4111, Fullerton, Ca. 92634, (714)871-8800 Bob Chamberlin
	Schott Optical Glass, York Ave., Duryea, Penn. 18642, (717)457-7485
Sh	Shell Chemical Co.
SW	Sargent Welch Chemical Corp.
T	Thiokol Chemical Div., 930 Lower Ferry Rd., Trenton, N.J. 08607, (609)396-4001
Tap	Tap Plastics Inc., 1212 Alameda, San Jose, Ca., (408)292-0685
Tech	Techform Labs, Los Angeles, Ca. 90061
Tr	Tra-con Inc., Medford, Ma. 02155
UC	Union Carbide
Uni	Uniroyal (800)243-2719
Upj	Upjohn Co., CPR Div., 555 Alaska Ave., Torrance, Ca. 90503
USI	USI Corp. c/o Plastic Systems, 50 Brigham St., Marlboro, Ma. 01752 (617)485-7390
VF	Valley-Fisher, 75 South St., Hopkinton, Ma 01748 (617)435-6831
VWR	Van Waters and Rogers, (408)263-9900, 2256 Junction, San Jose, Ca.
Wa	Wadsworth-Pacific, (415)321-3619
	Epoxy Technology Inc., 14 Fortune Dr., Billerica, Mass. 01821
WG	Westaro Gold and Platinum Co., 477 Harbor Blvd., Belmont Ca. 94002, (415)592-9440
WP	Westlake Plastics, PO Box 127, Lenni, Penn. 19052, (215)459-1000 Matsui, N.Y., N.Y.
	Plastic Sales, San Francisco, Ca. (415)550-1040

OTHER ABBREVIATIONS

ALUMINA	Aluminum oxide for thin layer chromatography. Obtained from Chemistry Stores at Stanford University.
CSW	A Li Tungsten product, the 6 to 10 micron powder
DEH	Dow epoxy hardner
LP3	A liquid polysulfide resin from Thiokol Corporation
DER	Dow epoxy resin
MPDA	Meta-phenaline-diamine, a good epoxy hardner. Use vendors B, handle, or rather don't handle with care. This product can be difficult to obtain fresh, should arrive in the form of whiteish flakes. When handling, take care to use gloves and apron, do not breath the powder. It is best stored in jars filled with dry nitrogen at 0C. When opening a new jar, allow it to equilibrate to RT first.
PHA	Parts per hundred parts by weight of A
PHE	Parts per hundred parts by weight of mixed epoxy
PHR	Parts per hundred parts by weight of RESIN, as opposed to total weight etc.
R1	Recipe 1: Heat the resin to 70C, add the MPDA and keep the mixture in the oven until the MPDA melts. Sift the W through a 100 mesh screen and add to the epoxy. Stir throughly, and outgass the mixture to a 100 micron vacuum. Cure at 40C for 1 hour, then leave in oven overnite at 70C.
R2	Recipe 2: Mix alumina to resin. Alumina is very light and fluffy and does not need to be sifted first. It is so light in fact, that any mixture having more than about 100PHR of it will be fixatropic and hard to pour. Next add the hardner, then stir throughly and outgass to 200 microns. Use an engraving tool on the beaker to facilitate pouring. Cure at RT for 48 hours.
R3	Recipe 3: Sift the W through a 100 mesh screen before adding to the resin at RT. Stir and outgass the mixture to 150 microns vacuum. Add the hardner, stir and outgass again. We have noted that epoxy hardned by DEH20, if exposed to the atmospheric moisture, will still be sticky after curing. This is called blushing and usually does not effect the experiment.

TABLE I (*Continued*)

R4 Recipe 4: Mix parts A and B and filler together, outgass to 100 microns vacuum, bake overnite at 70C.
R5 Recipe 5: Vacuum impregnation. To make these materials a vessel is required which is vacuum tight at the bottom and open at the top, i.e. a test tube or jig. The jig is mold released and the filler material is poured into it, usually no more than a third of the way to the top. Next the jig is warmed in an oven to the specified temperature to preheat it and bake on the mold release. The resin is melted, usually in the same oven at this time, and then the MPDA is added and allowed to melt into the resin. Thiokol may also be added at this time if specified. The mixture is stirred, then poured over the filler material, usually no more than two thirds of the way to the top. This assembly is outgassed till a vacuum of 100 microns is reached, usually in about 20 minutes depending on the size of the jig etc. When the vacuum is broken, the epoxy is forced into the filler material by atmospheric pressure. Bake at 70C overnight.
R6 Recipe 6: Parts A and B are stirred together, outgass to 100 microns vacuum, bake at 60C overnight.
R7 Recipe 7: Same as R6 but the material is post baked at 200C overnight. Material turns from red to black and the loss increases.
R8 Recipe 8: Stir components together throughly, outgass to 200 microns, pour into a jig at room temperature, leave at RT for about an hour, then place jig in 72C oven overnight.
R9 Recipe 9: Stir components together thorghly, outgass to 200 microns, pour in to a preheated jig and bake at 90C overnight
R10 Recipe 10: Melt resin, mix in alumina, outgass mix to 1mm, add DEH20, stir, outgass again to 1mm.
RT Room temperature, or about 20C
SiC Silicon carbide, 325 mesh or about 10 to 20 microns diameter, Cerac product number S1167
T1167 325 mesh tungsten from Cerac, product number T1167
V140 Versamid V140
W Tungsten powder, 1 to 2 microns diameter, Cerac product number T1166
This material is very fine and does not settle out of a heavier epoxy resin such as DER317 at RT

ABBREVIATED REFERENCES

AE Handbook of Tables for Applied Engineering Sciences
AS Alan Selfridge, Ph.D., Ultrasonic Devices, 3597 Middlefield Rd., Palo Alto, Ca. 94303 (415)327-1140
CRC Handbook of Chemistry and Physics, 45th Edition, Chemical Rubber Co., Cleveland Ohio, pg E-28
DP Dan Pettibone, Ph.D., Diasonics, Sunnyvale, Ca.
GC Genevieve Gonas, IEEE Transactions on Sonics and Ultrasonics, Mar 1983
JF John Fraser, Ph.D.
KF Kinsler and Frey, FUNDAMENTALS OF ACOUSTICS, John Wiley and Sons, 1962
LB LANDOLT-BORNSTEIN, Numerical Data and Functional Relationships in Science and Technology, New Series
GROUP II: Atomic and Molecular Physics
VOLUME 5: Molecular Acoustics by W. Schaaffs
EDITORS: K. H. Hellwege and A. M. Hellwege
PUBLISHER: Springer-Verlag, Berlin, Heidelberg, New York, 1967
This reference contains velocity and density information for just about any organic liquids. Other volumes in this work contains such information on various anisotropic solids and crystals.
M Panametrics Inc., Rt. 7 Box 2500, Richland, Wa. 99352 (509)627-5861 Telex 152997 Application Note 23
ME Materials Engineering, Dec 1983
RB Rick Baer, Ph.D., Hewlett Packard, Page Mill Rd., Palo Alto, Ca.
SIM Simmons, Gene 1922- Single crystal elastic constants and calculated aggregate properties: a handbook by Gene Simmons and Herbert Wang, 2nd ed. Cambridge, Mass. M.I.T. Press (1971) xv 370 pgs.

used for column headings here:

Loss	Attenuation
ρ	density in g/cm^3
σ	Poisson's ratio or $(1 - 2X)/(2 *(1 - X))$ where $X = (V_S/V_L)^2$
$\Delta V/\Delta T$	change of velocity per change in temperature given in m/s/°C referenced to 25°C.
V_L	acoustic longitudinal wave velocity in mm/μs
V_S	acoustic shear wave velocity in mm/μs
Z_L	acoustic impedance $= \rho * V_L$, in kg/(s * m^2) * 10^{-6}.

LOSS, or attenuation, is given in several different formats in these tables. The most specific way is with the @ symbol. The number before the @ is the loss in dB/cm, the number after the @ symbol is the frequency at which the attenuation was measured in MHz. The use of A= means the number given is alpha (nepers per cm) given in s^2/cm times 10^{-7}. To get loss in dB/cm multiply alpha by $8.686 * f^2$, where f is the frequency of interest in Hz. This representation obviously assumes that loss increases in proportion to frequency squared, and is most commonly used for low loss materials such as glass.

Transducer modeling programs will commonly assume loss increases just in proportion to the frequency to the first power. If this is the case then it is appropriate to use the material quality factor, or acoustic Q. To convert between dB/cm and Q the following equations can be useful:

$$Q = \frac{2 * \pi * (\text{Stored energy})}{\text{Energy dissipated per cycle}} \qquad (10)$$

$$Q = W_0 \frac{\text{Stored energy}}{\text{Average power loss}} \qquad (11)$$

$$Q = \frac{86.9 * \pi * f}{((\mathrm{dB/cm}) * \mathrm{velocity})}. \tag{12}$$

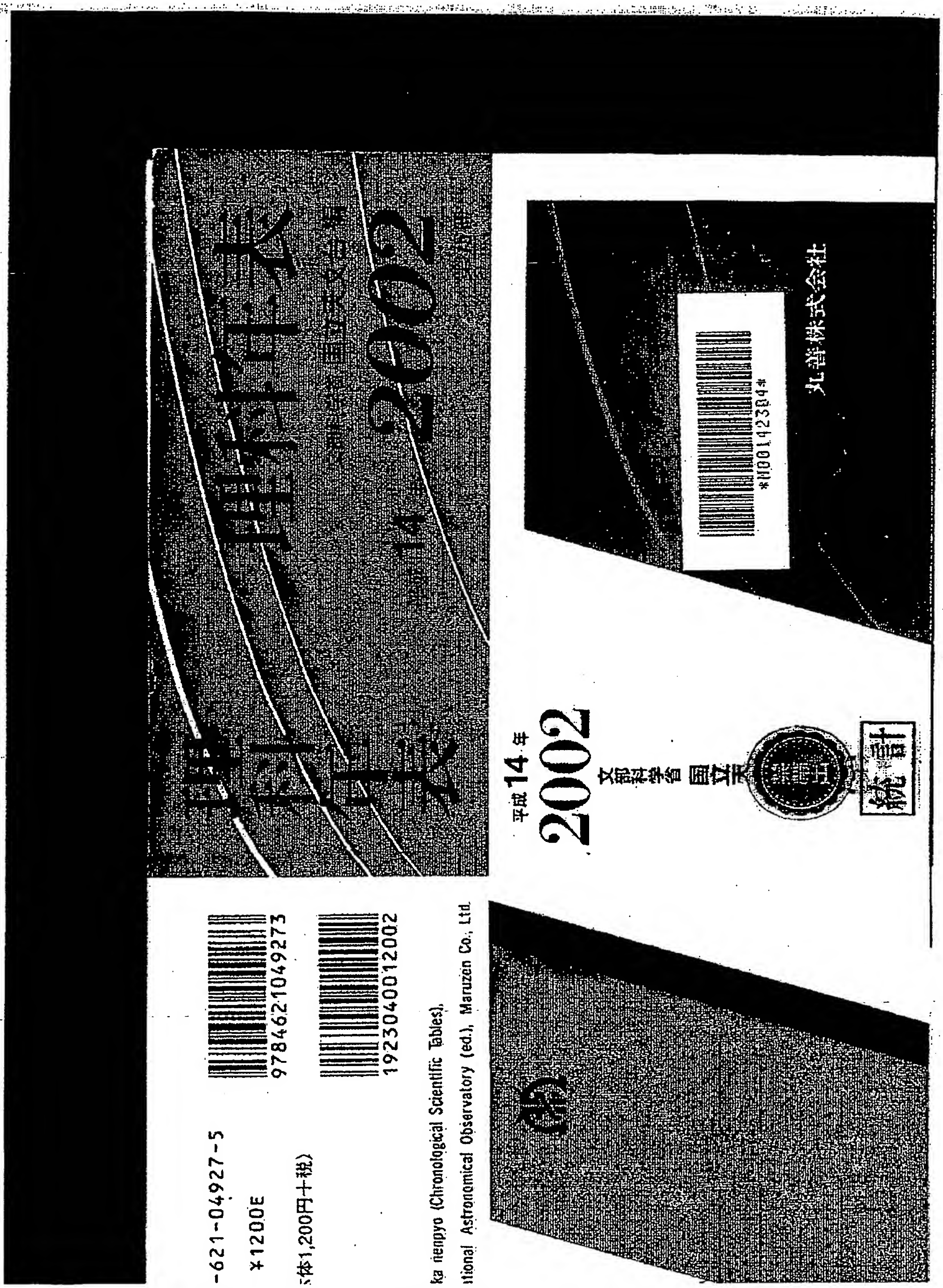
References

[1] B. A. Auld, *Acoustic Fields and Waves in Solids*, vol. I and II. New York: John Wiley, 1973.
[2] V. M. Ristic, *Principles of Acoustic Devices*. New York: John Wiley, N.Y., 1983.
[3] Fred Stanke, Schlumberger, Inc., Ridgefield, CT, private communication.

Alan R. Selfridge was born on February 27, 1954 in Midland, MI. He received the B.S. degree from the University of California at Davis in biomedical engineering in 1976, and the Ph.D. degree from Stanford University, Stanford, CA, in electrical engineering in 1983. His thesis work was on the design and measurement of ultrasonic transducers and transducer arrays.

He is currently self employed in Palo Alto, CA as a consultant in the design, fabrication, and measurement of ultrasonic devices. His primary career goal is to develop the state of the art in medical imaging so as to enable better prediction of birth defects.

Dr. Selfridge is currently the chairman of the Santa Clara Valley Group on Sonics and Ultrasonics.



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tional Astronomical Observatory (ed.), Maruzen Co., Ltd.

液体の粘度

(圧力は 1 atm=101 325 Pa，単位は 10^{-3} Pa·s)

物質	0℃	25℃	50℃	75℃	100℃
アセトン	0.402	0.310	0.247	0.200	0.165
アニリン	10.250	3.822	1.982	1.201	0.808
エチルアルコール	1.873	1.084	0.684	0.459	0.323
ジエチルエーテル	0.288	0.224	0.179	0.146	0.119
四塩化炭素	1.341	0.912	0.662	0.503	0.396
水銀	1.616	1.528	1.401	1.322	1.255
ひまし油	—	700	125	42.0	16.0
ベンゼン	—	0.603	0.436	0.332	0.261
メチルアルコール	0.797	0.543	0.393	0.294	0.227
硫酸	…	23.8	11.7	6.6	4.1

Kaye & Laby, 1986による．

気体の粘度

(1) 気体の粘度は数 10 Pa より数気圧に至る広い範囲において圧力にほとんど無関係である．
(2) 温度 T_1 K の粘度 η_1 が知れているとき，温度 T_2 K の粘度 η_2 はほぼ次式で与えられる．

$$\eta_2=\eta_1\left(\frac{T_1+C}{T_2+C}\right)\left(\frac{T_2}{T_1}\right)^{3/2}$$

C はサザランドの定数である．

(圧力は 1 atm=101 325 Pa，温度 20℃，単位 10^{-6} Pa·s)

物質	$\eta/10^{-6}$ Pa·s	C	物質	$\eta/10^{-6}$ Pa·s	C	物質	$\eta/10^{-6}$ Pa·s	C
アルゴン	22.3	142	酸素	20.4	128	二酸化炭素	14.7	240
一酸化炭素	17.4	102	水蒸気	12.1(100℃)	650	ヘリウム	19.6	—
塩素	13.2	350	水素	8.8	72	ベンゼン	7.5	…
空気	18.2	117	窒素	17.6	104	メタン	11.0	164

Kaye & Laby, 1986による．

表面張力

水の表面張力 (γ)

次表は温度 t℃ における水の表面張力 γ の値で，*印を施したものは水蒸気に対する値，その他は空気に対する値である．

(単位は 10^{-3} N·m^{-1})

t/℃	γ	t/℃	γ	t/℃	γ	t/℃	γ	t/℃	γ
−5	76.40	16	73.34	21	72.60	30	71.15	80	62.60
0	75.62	17	73.20	22	72.44	40	69.56	90	60.74
5	74.90	18	73.05	23	72.28	50	67.91	100	58.84
10	74.20	19	72.90	24	72.13	60	66.17	110	56.89*
15	73.48	20	72.76	25	71.96	70	64.41	120	54.89*

Landolt-Börnstein Tabellen (1956).

種々の物質の表面張力 (γ)

(単位は 10^{-3} N·m^{-1})

物質	接触する気体	t/℃	γ	物質	接触する気体	t/℃	γ
水素(液体)	その蒸気	−253.1	1.98	石油	空気	18	26
ヘリウム(液体)	その蒸気	−269.0	0.098	トルエン	その蒸気	20	28.53
ヘリウム(液体)	その蒸気	−271.6	0.354	ニトロベンゼン	空気	20	43.35
窒素(液体)	その蒸気	−203.1	10.53	二硫化炭素	空気	20	35.3
酸素(液体)	その蒸気	−183.0	13.55	パラフィン油[1]	空気	20	26.4
アンモニア水(20%)	空気	15	59.3	ヘキサン	空気	20	18.42
エチルアルコール	窒素	20	22.27	ベンゼン	空気	20	28.88
オリーブ油[2]	空気	20	32	メチルアルコール	窒素	20	22.55
グリセリン	空気	20	63.4	硫酸(98.5%)	空気	20	55.1
クロロホルム	空気	20	27.28	水銀	窒素	25	482.1
酢酸	空気	20	27.7	鉛	水素	350	442
ジエチルエーテル	その蒸気	20	16.96	鉄	ヘリウム	1570	1720
四塩化炭素	空気	20	27.03	金	水素	1200	1120
ジオキサン	その蒸気	20	33.55	塩化ナトリウム	窒素	803	117.0

1) 密度 0.91，2) 密度 0.847．

弾性に関する定数

次表において，E はヤング率で単位は Pa=N·m^{-2}，G は剛性率で単位は Pa，σ はポアソン比，k は体積弾性率で単位は Pa，κ は圧縮率で単位は Pa^{-1}．

一様な等方性の物質についてはこれらの量の間につぎの関係がある．

$$E=2G(1+\sigma)=3k(1-2\sigma),\quad \kappa=1/k$$

なおこれらの値はその過去の取扱い方によってかなり異なる．

物質	E/Pa	G/Pa	σ	k/Pa	κ/Pa^{-1}
	×10^{10}	×10^{10}		×10^{10}	×10^{-11}
亜鉛	10.84	4.34	0.249	7.20	1.4
アルミニウム	7.03	2.61	0.345	7.55	1.33
インバール[1]	14.40	5.72	0.259	9.94	1.0
カドミウム	4.99	1.92	0.300	4.16	2.4
ガラス(クラウン)	7.13	2.92	0.22	4.12	2.4
ガラス(フリント)	8.01	3.15	0.27	5.76	1.7
金	7.80	2.70	0.44	21.70	0.461
銀	8.27	3.03	0.367	10.36	0.97
ゴム(弾性ゴム)	(1.5–5.0)×10^{-4}	(5–15)×10^{-5}	0.46–0.49	—	—
コンスタンタン	16.24	6.12	0.327	15.64	0.64
黄銅(真鍮)[2]	10.06	3.73	0.350	11.18	0.89
スズ	4.99	1.84	0.357	5.82	1.72
青銅(鋳)[3]	8.08	3.43	0.358	9.52	1.05
石英(溶融)	7.31	3.12	0.170	3.69	2.7
ジュラルミン	7.15	2.67	0.335	—	—
タングステンカーバイド	53.44	21.90	0.22	31.90	0.31
チタン	11.57	4.38	0.321	10.77	0.93
鉄(軟)	21.14	8.16	0.293	16.98	0.59
鉄(鋳)	15.23	6.00	0.27	10.95	0.91
鉄(鋼)	20.1–21.6	7.8–8.4	0.28–0.30	16.5–17.0	0.61–0.59
銅	12.98	4.83	0.343	13.78	0.72
ナイロン-6,6	0.12–0.29	—	—	—	—
鉛	1.61	0.559	0.44	4.58	2.2
ニッケル(軟)	19.95	7.60	0.312	17.73	0.564
ニッケル(硬)	21.92	8.39	0.306	18.76	0.533
白金	16.80	6.10	0.377	22.80	0.44
パラジウム(鋳)	11.3	5.11	0.393	17.6	0.57
ビスマス	3.19	1.20	0.330	3.13	3.2
ポリエチレン	0.04–0.13	0.026	0.458	—	—
ポリスチレン	0.27–0.42	0.143	0.340	0.400	25.0
マンガニン[4]	12.4	4.65	0.329	12.1	0.83
木材(チーク)	1.3	—	—	—	—
洋銀[5]	13.25	4.97	0.333	13.20	0.76
リン青銅[6]	12.0	4.36	0.38	—	—

1) 36Ni，63.8Fe，0.2C　2) 70Cu，30Zn　3) 85.7Cu，7.2Zn，6.4Sn　4) 84Cu，12Mn，4Ni　5) 55Cu，18Ni，27Zn　6) 92.5Cu，7Sn，0.5P．おもに Kaye & Laby，1986による．

液体の圧縮率

次表は液体の温度一定の場合の圧縮率 $\kappa=\frac{1}{k}=-\frac{1}{v}\frac{dv}{dp}$ を示す．単位は (GPa)$^{-1}$．

液体	t/℃	p/atm	κ/(GPa)$^{-1}$	液体	t/℃	p/atm	κ/(GPa)$^{-1}$
アセトン	20	1	1.26	水銀	21.9	10 000	0.0300
アセトン	20	6 000	0.21	トルエン	20	1	0.91
エチルアルコール	20	1	1.11	二硫化炭素	20	1	0.93
エチルアルコール	20	5 000	0.22	ベンゼン	20	1	0.95
エーテル	20	1	1.87	水	20	1	0.45
エーテル	20	5 000	0.22	水	20	1 000	0.36
グリセリン	20	1	0.21	水	20	5 000	0.18
グリセリン	20	5 000	0.12	水	60	10 000	0.12
クロロホルム	20	1	1.01	メチルアルコール	20	1	1.23
水銀	21.9	1 000	0.0388	メチルアルコール	20	5 000	0.21

おもに Amer. Inst. Phys. Handbook. 3rd ed. による．1 atm=101 325 Pa

(19)

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Viscosity of Liquids (10⁻³Pa·s, Pressure 1atm=101.325Pa)

Material	0℃	25℃	50℃	75℃	100℃
Acetone	0.402	0.310	0.247	0.200	0.165
Aniline	9.450	3.822	1.982	1.201	0.808
Ethanol	1.673	1.084	0.684	0.459	0.323
Diethyl Ether	0.288	0.224	0.179	0.146	0.119
Carbon Tetrachloride	1.341	0.912	0.662	0.503	0.395
Hg	1.616	1.528	1.401	1.322	1.255
Castor Oil	_	700	125	62.0	16.9
Benzene	_	0.603	0.436	0.332	0.263
Methanol	0.797	0.543	0.392	0.294	0.227
Carbonic Acid	_	23.8	11.7	6.6	4.1